Inertial electrostatic confinement

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Inertial electrostatic confinement (often abbreviated as **IEC**) is a concept for retaining a plasma using an electrostatic field. The field accelerates charged particles (either ions or electrons) radially inward, usually in a spherical but sometimes in a cylindrical geometry. Ions can be confined with IEC in order to achieve controlled nuclear fusion.

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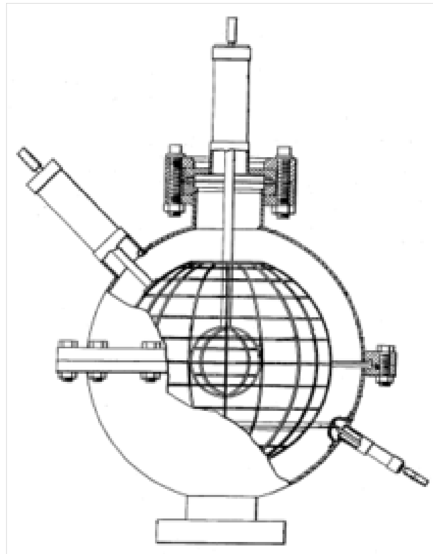
Approaches to IEC

The best-known IEC device is the Farnsworth-Hirsch Fusor.[1] This



US3530497 — Hirsch–Meeks fusor. The two concentric electrodes can be seen in the center of the reaction chamber.

system consists largely of two concentric spherical electrical grids inside a vacuum chamber into which a small amount of fusion fuel is introduced. Voltage across the grids causes the fuel to ionize around them, and positively charged ions are accelerated towards the center of the chamber. Those ions may collide and fuse with ions coming from the other direction, may scatter without fusing, or may pass directly through. In the latter two cases, the ions will tend to be stopped by the electric field and re-accelerated toward the center. Fusors can also use ion guns rather than electric grids.

The fusor's popularity is largely due to the fact that simple versions can be built for as little as $500 to $4000 (in 2003 US dollars), making it accessible to hobbyists, science fair contestants and small universities. Even these simple devices can reproducibly and convincingly produce fusion reactions, but no fusor has ever come close to producing a significant amount of fusion power. They can be dangerous if proper care is not taken because they require high voltages and can produce harmful radiation (neutrons, gamma rays and x-rays). The basic IEC device has been developed as a commercial neutron generator for industrial applications: first with the trade name FusionStar and now NSD-Fusion.

Two newer approaches both try to solve a problem found in the fusor, which is that some ions collide with the grids. This heats the grids, sprays high-mass ions into the reaction chamber, pollutes the plasma, and cools the fuel. The Polywell
uses a magnetic field to trap a quantity of electrons, fuel ions are then accelerated directly into the middle where they are trapped by the electron cloud that forms a "virtual electrode". Another modern approach uses a Penning trap to trap electrons in a system otherwise similar to the Polywell.[2][3]

Critique

According to Todd Rider in A general critique of inertial-electrostatic confinement fusion systems (http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=PHPAEN000002000006001853000001&ic
, net energy production is not viable in IEC fusion for fuels other than D-T, D-D, and D-He3, and breakeven operation with any fuel except D-T is unlikely. The primary problem that he discusses is the thermalization of ions, allowing them to escape over the top of the electrostatic well more rapidly than they fuse. He considers his paper optimistic because he assumes that core degradation can be countered.

Nevins makes an argument similar to Rider's in [W.M. Nevins, Phys. Plasmas <2> (10), 3804 (October, 1995)], where he shows that the fusion gain (ratio of fusion power produced to the power required to maintain the non-equilibrium ion distribution function) is limited to 0.1 assuming that the device is fueled with a mixture of deuterium and tritium. A fusion gain of about 10 is required for net energy production.

References

1. **^** R. Hirsch, "Inertial-Electrostatic Confinement of Ionized Fusion Gases," *Journal of Applied Physics* **38**, 4522 (1967).
2. **^**
R.W. Bussard, "Some Physics Considerations of Magnetic Inertial-Electrostatic Confinement: A New Concept for Spherical Converging-flow Fusion," *Fusion Technology* **19**, 273 (1991).
3. **^** D.C. Barnes, R.A. Nebel, and L. Turner, "Production and Application of Dense Penning Trap Plasmas," *Physics of Fluids* **B 5**, 3651 (1993).

External links

- University of Wisconsin-Madison IEC homepage (http://fti.neep.wisc.edu/iec/MainPage/ftisite1.htm)
  - IEC Overview (http://fti.neep.wisc.edu/iec/IEC_Overview.pdf)
- From Proceedings of the 1999 Fusion Summer Study (Snowmass, Colorado):
  - Summary of Physics Aspects of Some Emerging Concepts (http://www.ap.columbia.edu/SMproceedings/7.EmergingConcepts/7.Physics.pdf)
- Inertial-Electrostatic Confinement (IEC) of a Fusion Plasma with Grids (http://www.ap.columbia.edu/SMproceedings/11.ContributedPapers/11.Nadler.pdf)
- Fusion from Television? (American Scientist Magazine, July-August 1999) (http://www.americanscientist.org/template/AssetDetail/assetid/15723)

- Todd Rider's 1994 Masters Thesis
  - A General Critique of Inertial-Electrostatic Confinement Fusion Systems (https://dspace.mit.edu/bitstream/1721.1/29869/1/31763419.pdf)
- Talk by Dr. Robert Bussard, former Asst. Director of the Atomic Energy Commission and founder of Energy Matter Conversion Corporation (EMC2):
  - Should Google Go Nuclear? Clean, cheap, nuclear power (no, really) (http://video.google.com/videoplay?docid=1996321846673788606) Google Tech Talk November 9, 2006.
  - 'The Advent of Clean Nuclear Fusion: Superperformance Space Power and Propulsion' cited in the Dr. Bussard's Talk. (http://www.askmar.com/ConferenceNotes/2006-9%20IAC%20Paper.pdf) 57th International Astronautical Congress 2006 Author: Dr. Robert W. Bussard

Fusion power

Atomic nucleus | Nuclear fusion | Nuclear power | Nuclear reactor | Timeline of nuclear fusion | Plasma physics | Magnetohydrodynamics | Neutron flux | Fusion energy gain factor | Lawson criterion

Methods of fusing nuclei

Magnetic confinement: – Tokamak – Spheromak – Stellarator – Reversed field pinch – Field-Reversed Configuration – Levitated Dipole
Inertial confinement: – Laser driven – Z-pinch – Bubble fusion (acoustic confinement) – Fusor (**electrostatic confinement**)
Other forms of fusion: – Muon-catalyzed fusion – Pyroelectric fusion – Migma – Polywell – Dense plasma focus

List of fusion experiments

Magnetic confinement devices
ITER (*International*) | JET (*European*) | JT-60 (*Japan*) | Large Helical Device (*Japan*) | KSTAR (*Korea*) | EAST (*China*) | T-15 (*Russia*) | DIII-D (*USA*) | Tore Supra (*France*) | TFTR (*USA*) | NSTX (*USA*) | NCSX (*USA*) | UCLA ET (*USA*) | Alcator C-Mod (*USA*) | LDX (*USA*) | H-1NF (*Australia*) | MAST (*UK*) | START (*UK*) | ASDEX Upgrade (*Germany*) | Wendelstein 7-X (*Germany*) | TCV (*Switzerland*) | DEMO (*Commercial*)

Inertial confinement devices
Laser driven: — **NIF** (*USA*) | OMEGA laser (*USA*) | Nova laser (*USA*) | Novette laser (*USA*) | Nike laser (*USA*) | Shiva laser (*USA*) | Argus laser (*USA*) | Cyclops laser (*USA*) | Janus laser (*USA*) | Long path laser (*USA*) | 4 pi laser (*USA*) | **LMJ** (*France*) | Luli2000 (*France*) | GEKKO XII (*Japan*) | ISKRA lasers (*Russia*) | Vulcan laser (*UK*) | Asterix IV laser (*Czech Republic*) | HiPER laser (*European*)
Non-laser driven: — Z machine (*USA*) | PACER (*USA*)

See also: International Fusion Materials Irradiation Facility